Subject. Date.



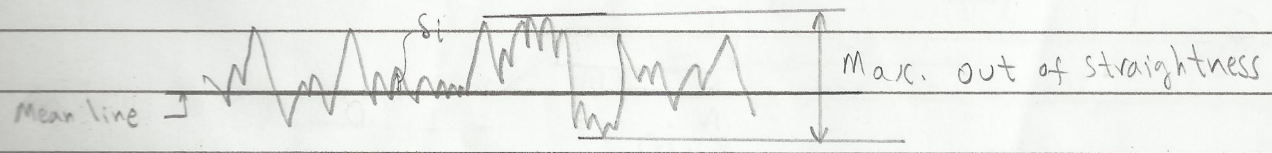
# 4- Out of straightness

*- Horizontal surface: It is the tangent to earth or any bubble
- Smooth surface: It is the surface with no roughness
- Flat surface: It is the surface which is perfect surface

* Form errors:
- Out of straightess
- Out of flatness
- Out of squarness
- out of roundness
- out of parallelism
- others

*- Straightness measurements include surface inclination, zero error and B.Gs errors
- Errors are removed by FWD & BWD readings

*- Out of Straightness: It is the depature of surface from the true straight line
- Max. out of straightness: It is the min. distance between 2 lines containing the irregularities of edge tested




(Si) Out of straightness of point (i)

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* Experimental procedure;

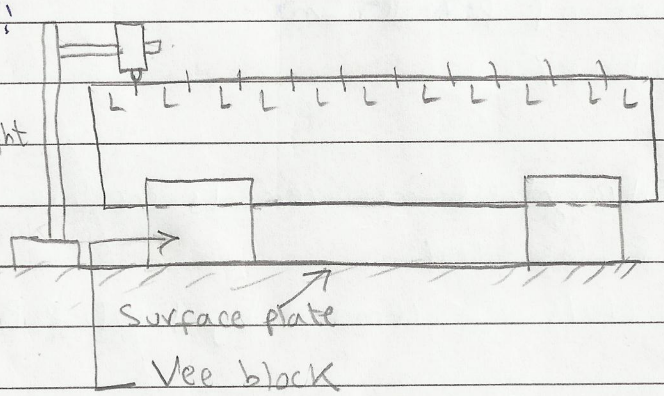
1_ The entire length of the edge is divided into equal intervals
2_ The variations in heights of the end points at each interval are determined experimentally
3_ The experimental readings are related to a certain datum
4_ The complete profile of the edge is obtained by linear interpolation
5_ The heights of the discrete points may be determined by using dial indicator, sensitive level or autocollimator

* Measuring straightness;

1_ Using dial indicator;

Max. reading

| Point | Reading | Relative height |
|---|---|---|
| 1 | x | x |
| 2 | y | x+y |
| 3 | z | x+y+z |
| ⋮ | ⋮ | ⋮ |



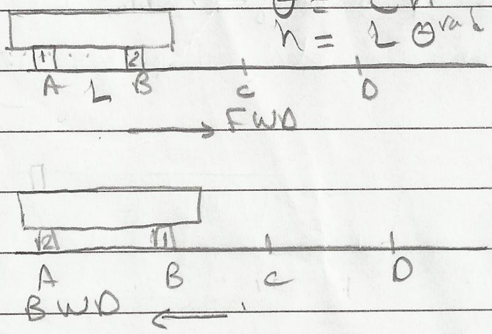

2_ Using sensitive levels;

\- Block sensitive level;

Level constant — No. of devisions moved by bubble

$$\theta = C n$$
$$h = L \theta^{rad}$$

| Line | FWD (A-B) | BWD (B-C) | Average (by sign) |
|---|---|---|---|
| B_A | x | y | $\frac{x+y}{2}$ |
| C_B | ⋮ | ⋮ | ⋮ |
| D_C | ⋮ | ⋮ | |

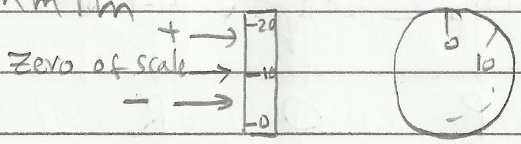



| Point | Relative heigh |
|---|---|
| A | 0 |
| B | B_A |
| C | B_A + C_B |
| ⋮ | ⋮ |

- Using optical clinometer:
- As sensitive level but reading is to $\theta'$

$$h = L \tan\left(\frac{\theta'}{60}\right)$$

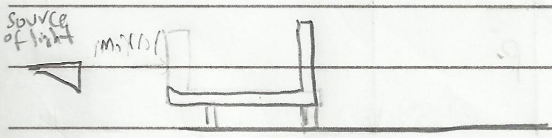
- Using micrometer clinometer
- S.V. = 0.01 mm/m

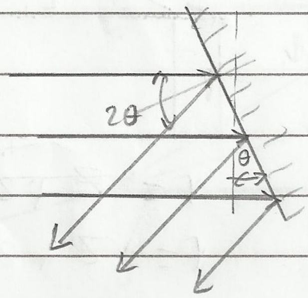



$h =$ Reading $- 10$

$$\theta = \frac{h\,(mm)}{1000\,(mm)}\ [rad]$$

3 - Using autocollimator:

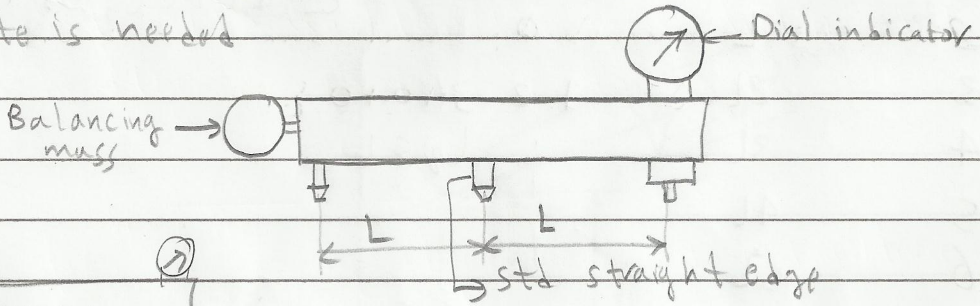


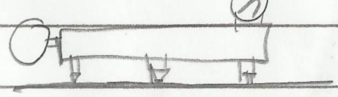



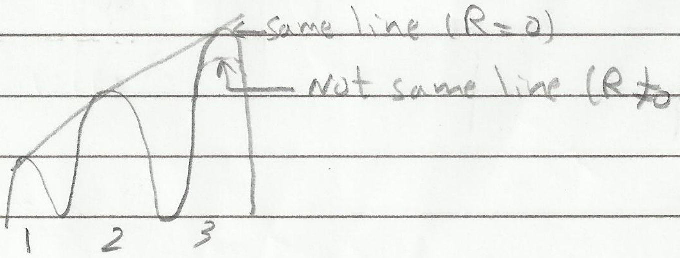


Calibrated scale

4 - Using bar comparator (Rotchdal arm)
- No reference plate is needed





Set to zero




1 - 2 - 3 ⇒ (3) w.r.t. (1 - 2) line

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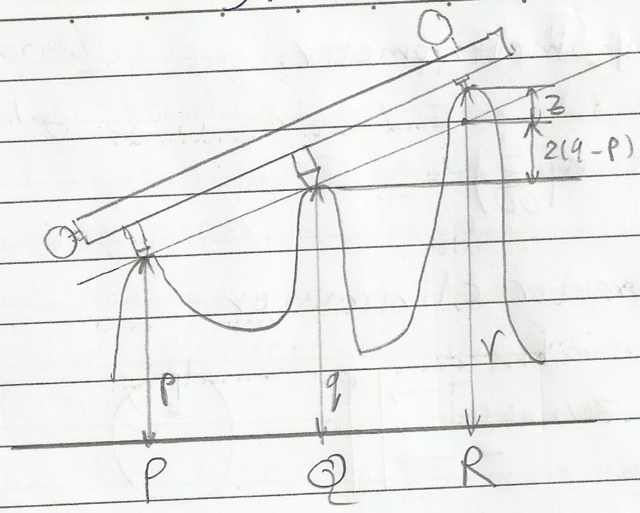
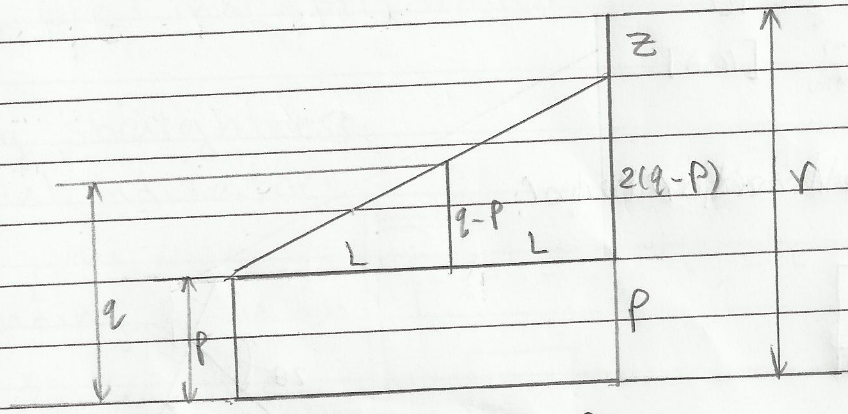



$$r = z + 2(q-p) + p$$

$$r = z + 2q - p$$

| Point | Length(x) | Height(y) |
|---|---|---|
| 1 | 0 | 0 ⇐ It acts as inclination of plane |
| 2 | L | 0 |
| 3 | 2L | 1-2-3+0+0 |
| 4 | 3L | ما قبلها |
| 5 | 4L | ⋮ |
| 6 | 5L | ⋮ |
| ⋮ | ⋮ | |

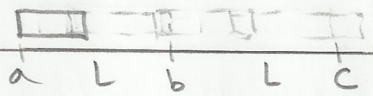
## * Calibration of Rotchdale arm (Arm comparator):

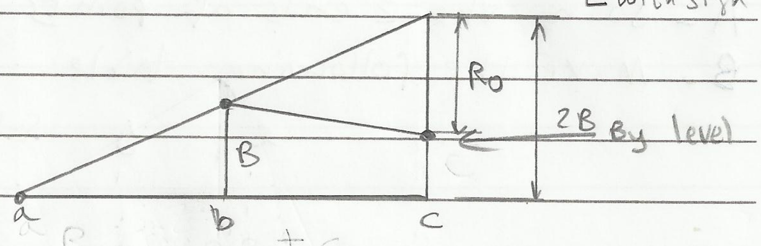
1- Take a reference reading on straight edge ($R_0$) to correct all reading to ($R - R_0$)

2- Using sensitive level

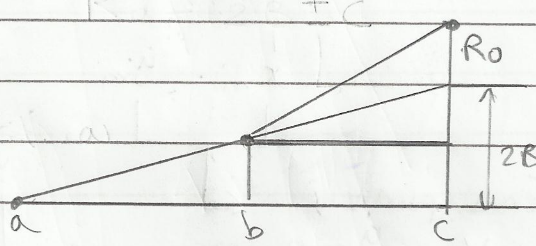
- Take a reading on line abc using Rotchadle arm ($R_h$)
- Determine the level of point (b) & (c) relative to (a) using sensitive level
- Determine the level of (c) relative to line $\overline{ab}$ math ($R_c$)
- Correct all readings to $R - C$ ; $C = R_h - R_0$

with sign




$$R_0 = C - 2B$$

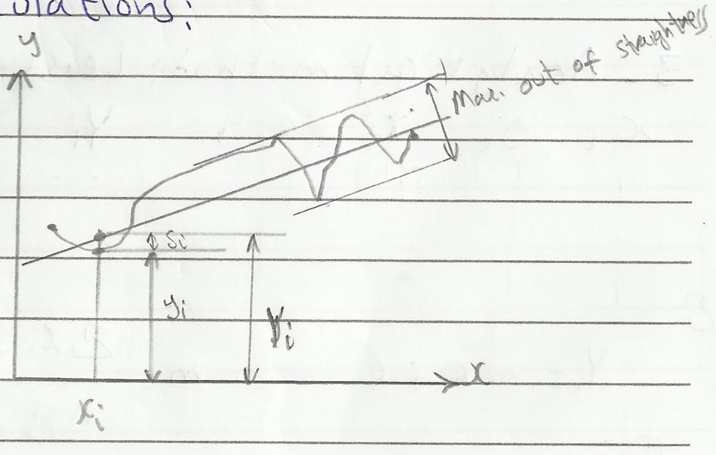



## * The out of straightness calculations:

Real Mathematical

$\delta_i = y_i - Y_i$

Max. $\delta_i = |\delta_{i\,max}| + |\delta_{i\,min}|$

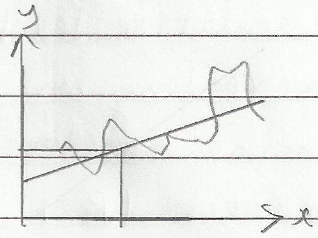


## 1- Graphical method:

A- Plot experimental readings

B- Plot a line repsenting the straight profile such that area under line = area above line

$$Y = mx + C \; ; \; m = \frac{\Delta y}{\Delta x}$$




## 2- Semi-analytical method:

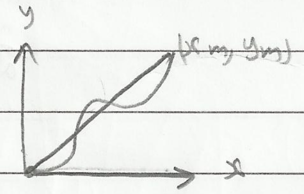
A- Join the 2 ends of points

B- Make the following table

| $x$ | $y$ | $\delta = y_i - Y_i$ |
|---|---|---|
| ⋮ | ⋮ | |
| $x_m$ | $y_m$ | 0 |

End point

$$Y_i = \frac{y_{m-0}}{x_{m-0}} x_i$$




## 3- Analytical method: Least square method;

| $x_i$ | $y_i$ | $x_i^2$ | $x_i y_i$ | $Y_i$ | $\delta_i$ |
|---|---|---|---|---|---|
| ⋮ | ⋮ | ⋮ | ⋮ | | |
| $\Sigma$ | | | | | |

$$Y_i = m x_i + C$$

$$m = \frac{n \Sigma x_i y_i - \Sigma x_i \Sigma y_i}{n \Sigma x_i^2 - (\Sigma x_i)^2}$$

$$C = \frac{\Sigma x_i^2 \Sigma y_i - \Sigma x_i \Sigma x_i y_i}{n \Sigma x_i^2 - (\Sigma x_i)^2}$$